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SEISMIC DATA ANALYSIS CENTER FINAL REPORT

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Seismic Data Analysis Center

Teledyne Geotech, 314 Montgomery Street, Alexandria, Virginia 22314

1 NDVEMBER 1976

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During the contract period, a Communications and Control Processor (CCP) was installed, thus adding the final element to the overall hardware system required to handle VELA data in the SDAC.

Three IBM computers were available 24 hours per day throughout the contract for real-time operations and batch processing. The operating system of one of these, a 360/44, was replaced with a more efficient time-sharing system which permits aeeess to the computer via remote terminals.

SDAC personnel filled more than 200 requests for data from 46 foreign and domestic companies, agencies, and institutions, and maintained on magnetic tape comprehensive seismicity files from the U.S., Sweden, Norway and France.

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In the area of network development, a new software system was installed which detects amplitudes above a prescribed level on seismograms recorded by the VELA network. A companion system that processes the output from the amplitude detector was brought nearer to eompletion with the development of additional code and the acquisition of an interactive graphics system.

SEISMIC DATA ANALYSIS CENTER FINAL REPORT

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ABSTRACT

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

I. INTRODUCTION

This final report summarizes the work performed at the Seismic Data Analysis Center in Alexandria, Virginia, during the period 01 July 1975 through 30 September 1976. The activities described here were accomplished under Contract F08606-76-C-0004, and this report fulfills Data Item A003 of the Data Requirements List in that contract.

Sections II through V of this report are discussions of the operations, programming, and maintenance of the equipment in the SDAC, and a description of the data services provided. These four sections correspond to Tasks 4.1 through 4.4 in the Statement of Work (SOW), respectively. The remainder of this report also follows the organization of the SOW, in that the work accomplished in Tasks 4.5 and 4.6 corresponds, respectively, to Parts VI and VII.

As discussed in Part II, three IBM general-purpose computers, i.e., a 360/44 and two 360/40's, were operated 24 hours per day during the term of the contract. The 360/44 batch processor utilized several operating systems to support in-house research efforts and data services. One 360/40 performed as a real-time amplitude detector while the second 360/40 acted in concert with a PDP-11/35 to support the development of software for the Network Event Processor. SDAC scientists used a DEC PDP-15/50 interactive processor to complete the A/D conversions, to evaluate data recorded by the Special Data Collection System, and to study data from new Seismic Research Observatory (SRO) stations using a special program which allows the scientist to scroll data and compute amplitude and period automatically. The addition of a Communications and Control Processor early in 1976 completed the hardware elements required to handle on-line data from the VELANET stations. Due to special training courses by the manufacturer and training sponsored by SDAC, operations and maintenance personnel were able to assume responsibility for the system at an early date.

Part IV summarizes the work performed by maintenance personnel during the reporting period. Preventive and corrective maintenance for most of the in-house systems was accomplished by the manufacturers including IBM, DEC, Calcomp, and Memorex. Teledyne maintained terminals, plotters, timing systems, communications modems, ARPANET interfaces, the analog equipment, and the NEP graphics system which includes a PDP-11/35 controller, an Evans and Sutherland picture system and an Ann Arbor alphanumeric terminal. Our plans to maintain the hardware used in the VELANET were discussed in a special document submitted to the VSC in March 1976.

Services rendered to the government and to participants in the VELA program are discussed in Part V. In compliance with Task 4.4, we provided facilities and other services to the VSC and to Texas Instruments. Moreover, we filled 207 data requests for 46 individual groups working in the VELA program. SDAC

personnel established and updated a digital file of worldwide seismicity information including data from the National Earthquake Information Service in the United States, from Sweden, Norway, and France.

Research scientists at the SDAC completed 18 reports, 10 technical memoranda, and two special studies in fulfillment of Task 4.5 of the SOW. Four of the reports discussed subjects related to magnitude estimates versus yield, three reports concerned mixed signals, and three related to source discriminants such as the determination of source depth and M_S versus m_b. Two of the eight remaining reports covered the subject of earthquakes in Tibet having explosion-like M_S versus m_b values, three summarized evasion studies, and three were pertinent to the detection capability of arrays.

Three of the memoranda summarized the detection capability of the Norwegian Seismic Array (NORSAR), two pertained to source location, and two concerned the detection capability of the Large Aperture Seismic Array (LASA) in Montana. Of the remaining memoranda, one each was devoted to the subjects of cube-root scaling for explosions, the effect of regional attenuation on estimates of body-wave magnitude (m_b), and long-period noise recorded at the Korean Seismic Research Station (KSRS).

Among the more significant contributions of these studies were the determinations that: the NORSAR array contains many redundant seismometers; the difference between magnitudes based on S waves and Rayleigh waves is a source diagnostic for worldwide earthquakes and underground nuclear explosions at NTS and on Amchitka; the M_S versus m_b discriminant fails for specific earthquakes in Tibet; both simple and complex earthquakes originate within small areas on the Kamchatka Penninsula; and finally, differences in attenuation account for differences in event magnitude computed at teleseismic distances in eastern and western United States.

VELANET capabilities (Task 4.6) were increased with the completion of a new detection processor (DP) early in 1976. The capability of the Network Event Processor which is the system that accepts outputs from the new DP, improved with the addition of a new graphics system and controller, and with the implementation of new software.

II. OPERATIONS

This section of the report concerns the operation of government-furnished equipment including: 1) processors used in a realtime mode to receive and process data from remote seismic recording stations; 2) processors operating in a near realtime mode to analyze and store data from the realtime system; and 3) those used in the "batch" mode to support researchers and data specialists.

Realtime Operations

Software classes and Acceptance Test training on the Communications and Control Processor (CCP) began on 29 March 1976. By June 1976 training of support programmers had progressed to the point where accurate records could be kept of the performance of the realtime system. Table 1 summarizes the performance of the various components comprising the realtime system including the CCP, the Interface Message Processor (IMP), and the Detection Processor (DP).

As shown in Table 1, the reliability of the overall realtime system improved from 83% in June, July, and August 1976, to 93% in September 1976. Contributing to the 7% data loss in September were the CCP (5%) and the new DP (2%). Of the 5% data loss by the CCP, almost 3% resulted from the fact that the CCP discards data when the IMP data queues are full.

Based on the experienced recording hours, 99% of the LASA data and 85% of the NORSAR data were recorded. Data were transmitted to the Seismic Input Processor (SIP) 93% of the time.

360/44

Three operating systems, GRASP, TS44, and DOS, were used in the 360/44 computer to support the research and service efforts at the SDAC during the contract period. An accounting program was used to identify users, to follow core allowcation, to record elapsed CPU and wall-clock time, to log the type of termination experienced by each program, and to note hardware problems. The results of this automatic record-keeping procedure are given in Tables 2 through 8.

Table 2 documents the use of the GRASP system during the 13-month period beginning 01 July 1975 and ending 31 July 1976 at which time GRASP was discontinued in favor of the more efficient TS44 system which utilizes remote terminals to access the computer. The gradual effort of changing to the new system is clearly shown in column six entitled "Grasp Utilization". At the beginning of the contract the system used about 76% of the time available to it while only 17% of the available time was used in the final month of operation. This effect is also observed in Table 3 in the column entitled TS44. These data show that the amount of block time assigned to TS44 almost tripled over the period of operation.

The three principal users of the GRASP system were Texas Instruments personnel, SDAC researchers, and SDAC services personnel; together they accounted for 82% of the system use, as shown in Table 4.

The results of operating the 360/44 computer under DOS are given in Table 5. The reader's attention is directed to the first line in the table which shows that over 50% of the total time available in the final two months of the contract was used to operate the TS44 system. Large amounts of DOS time during this two-month period were also consumed by Texas Instruments and by SDAC personnel who develop and improve the system and provide data services.

A total of 43,133 computer runs was made using the TS44 system during the 15-month term of the contract. Research scientists at the SDAC received 34% of the total runs as indicated in Table 6 while Texas Instruments personnel received 15%. The remaining 51% was distributed among several users including SDAC employees working in data services and system development.

Table 7 is a record of TS44 monthly utilization in terms of hours and number of runs. In July 1975 the table shows that the system was used for a period of 104 hours; by the end of the contract the monthly usage had increased nearly four times. During the same period the number of runs increased by a factor of 2.6.

360/40B

Early in the contract the IBM 360/40B computer was dedicated to the development of the Network Event Processing (NEP) system. This fact is illustrated in Table 8 which shows that work associated with NEP consumed 54% of the total operating time of the computer during the 15-month period. Although the prime role of the 360/40B was to support NEP, other users were free to use the system during the idle periods. As a result, the computer continued its support of batch processing for other in-house efforts to the extent shown in Table 8.

PDP-15/50

The work done by scientists using this system contributed significantly to our use of the Seismic Research Observatory data and seismograms recorded by stations in the Special Data Collection System. These efforts are summarized in Table 9 as "In-House Users". "Systems Development" was also accomplished by SDAC personnel, and the principal "Outside User" was Texas Instruments.

Analog

The analog processing equipment in the SDAC includes a TR48 computer, tape drives, direct-write oscillographs, and panels through which information

is routed to other analog units and to the PDP-15/50 digital computer. This equipment was used principally during the reporting period to perform analog-to-digital conversions of data from the SDCS operations and to convert to digital format data selected by the research section. The oscillographs were used infrequently to quality control data.

TABLE I
REALTIME SYSTEM PERFORMANCE (IN HOURS)

	JUNE (1976)	JULY	AUGUST	SEPTEMBER
Total Possible Recording Hours	720.0 (100.0%)	744.0 (100.0%)	744.0 (100.0%)	720.0 (100.0%)
CCP Downtime				
--Down Due to Testing and Maintenance	67.4 (9.4%)	38.4 (5.1%)	56.3 (7.6%)	11.7 (1.6%)
--Down Due to CCP "Self-Restarts"	--	1.5 (.2%)	.5 --	.6 --
--Down Due to CCP "Manual Reloads"	--	3.9 (.5%)	1.0 (.1%)	3.5 (.5%)
Pluribus Imp Downtime	.0 --	.0 --	2.1 (.4%)	3.3 (.5%)
DP Downtime				
--Down Due to Testing and Maintenance	7.6 (1.0%)	20.6 (2.8%)	3.7 (.5%)	4.7 (.7%)
--Down Due to System Crashes	--	--	18.9 (2.5%)	9.2 (1.3%)
Data Loss Due to Pluribus Imp Queues Not Accepting Data. Data is discarded by the CCP when the Imp data queues are full. The actual amount of data loss is unknown because the discarded data "packets" are of variable size. Past CCP performance has shown that 5-8 seconds is the approximate value per packet. For this report, the 8-second value is used.	47.9 (6.7%)	58.6 (7.9%)	45.0 (6.1%)	20.4 (2.8%)
TOTAL EXPERIENCED RECORDING HOURS*	597.1 (82.9%)	620.9 (83.5%)	616.4 (82.8%)	666.6 (92.6%)
LASA Statistics**				
--LASA Data Missing Due to AT&T Line Problems	5.5	Detail Not Available	1.8	2.1
--LASA Data Missing Due to LASA Data Center Problems	42.9		18.2	4.8
--Total LASA Data Missing	48.4 (8.1%)	163.5 (26.3%)	20.0 (3.2%)	6.9 (1.0%)
--Total LASA Data Recorded	548.7 (91.9%)	457.5 (73.7%)	596.4 (96.8%)	659.8 (99.0%)

TABLE 1 (Continued)

	JUNE (1976)	JULY	AUGUST	SEPTEMBER
NORSAR Statistics**				
--Total NORSAR Data Missing Due to Site or Telco. Line	309.6 (51.9%)	158.1 (25.5%)	164.9 (26.7%)	97.1 (14.6%)
--Total NORSAR Data Recorded	287.5 (48.1%)	462.9 (74.5%)	451.5 (73.3%)	569.6 (85.4%)
--NORSAR EP Results Received (180 One-Second Messages = 1 NORSAR EP File)	35565 Files	65773 Files	61189 Files	65096 Files
--DP Detections	3041	2297	2471	3015
SIP (Mass Store) Statistics**				
--SIP Downtime Recognized by the CCP	11.3 (1.0%)	148.8 (23.2%)	131.6 (21.4%)	47.1 (6.9%)
--Data Transmitted to SIP	593.4 (99.0%)	492.7 (76.8%)	484.7 (78.6%)	633.4 (93.1%)

* Based on assumption that all sources of data loss are independent.

** Based on Total Experienced Recording Hours.

TABLE II
UTILIZATION IN HOURS OF THE GRASP SYSTEM ON THE 360/44
FOR THE PERIOD 01 JULY 1975 THROUGH 31 JULY 1976

Month	Total Hours In Month	Block Time*	Wall Clock Time Remaining	Available GRASP Time**	GRASP Utilization	Background Idle	Foreground Idle
July 1975	744	280	464	928	703	47	178
Aug	744	216	528	1056	671	87	298
Sept	720	187	533	1066	603	156	307
Oct	744	248	496	992	574	144	274
Nov	720	238	482	964	391	236	337
Dec	744	220	524	1048	384	260	404
Jan 1976	744	221	523	1046	516	170	360
Feb	696	249	447	894	463	175	256
Mar	744	470	274	548	248	108	192
Apr	720	360	360	720	289	310	121
May	744	391	353	706	307	202	197
June	720	336	384	768	258	151	359
July	744	393	351	702	119	261	322
Aug & Sept			GRASP DISCONTINUED				
TOTALS	10992	3809	5719	11438	5526	2307	3605

* Both partitions in GRASP are dedicated in the block mode.

** Wall clock time is available to each of two partitions operating simultaneously.

TABLE III
DISTRIBUTION OF 360/44 BLOCK TIME IN HOURS

	Class.	Sys.	Ops.	PS44	TS44	Down
JUL	6	24	6	29	104	110
AUG	4	33	9	19	125	25
SEP	3	34	7	5	114	24
OCT	11	4	8	17	138	70
NOV	11	6	7	53	151	10
DEC	4	4	5	1	182	24
JAN	2	14	6	3	191	6
FEB	1	16	5	7	201	20
MAR	21	157	5	5	268	14
APR	6	81	5	-	250	17
MAY	12	57	6	-	283	34
JUN	15	32	4	2	276	7
JUL	15	59	5	2	283	29
	111	521	78	143	2566	390

TABLE IV

USERS OF GRASP FOR THE PERIOD 01 JULY 1975 TO 31 JULY 1976

	Runs	Duration (hrs)	% of GRASP Utilization
Research	3448	914	17
T.I.	9179	2834	51
Data Services	2744	793	14
Programming for 360/44	2083	447	8
Programming for PDP-15	42	4	--
A/D Formats	954	122	2
New DP	132	5	--
DP for LASA	239	24	--
LDC Software Revision	1	1	--
DP Documentation	23	1	--
Maintain Seismicity Data Files	421	83	2
SDCS	1167	209	4
Expanded VELA Network	235	36	1
VSC	25	4	--
NEP	558	49	1
	21251	5526	100%

(47% of available GRASP time)

TABLE V
UTILIZATION OF THE 360/44 OPERATING UNDER DOS
AFTER GRASP DISCONTINUANCE

	AUG (Hrs)	SEP (Hrs)	TOTAL (Hrs)
TS44	354	391	745
Classified	7	10	17
Systems Development	51	26	77
Texas Instruments	129	89	218
Data Services	17	23	40
Programming for 360	4	1	5
NEP	1	14	15
DP	1	-	1
Research	-	2	2
Idle	180	164	344
TOTAL	744	720	1464

TABLE VI
UTILIZATION OF TS-44 SYSTEM FOR THE PERIOD
01 JULY 1975 THROUGH 30 SEPTEMBER 1976

	No. of Runs	Percent of Utilization
Research	14,830	34%
T.I.	6,514	15%
Data Services	2,264	5%
Programming for 360/44	6,727	16%
Programming for PDP-15	129	-
DP	66	-
Documentation and Program Library	2	-
Systems	5,242	12%
SDCS	2,835	7%
NEP	934	2%
March, 1976 (all users)*	3,590	8%
	43,133	99%

* A breakdown of the total number of runs in March 1976 is not available.

TABLE VII
MONTHLY USE OF THE TS44 SYSTEM

HOURS	RUNS	MONTH
104	1696	JUL (1975)
125	1923	AUG
114	1732	SEP
138	2017	OCT
151	2216	NOV
182	2234	DEC
190	2662	JAN (1976)
201	2818	FEB
268	3590	MAR
250	2928	APR
283	2961	MAY
276	4125	JUN
283	3858	JUL
354	4036	AUG
391	4337	SEP
3311	43133	TOTAL

TABLE VIII
SUMMARY OF 360/40B USE
FROM 01 JULY 1975 THROUGH 30 SEPTEMBER 1976

Description	Hours	%
A/D Formats	14	-
Research	35	-
Texas Instruments	22	-
DP for LASA	305	5%
NEP	3206	54%
Expanded VELA Network	308	5%
Programming for 360	788	13%
Data Services	772	13%
VSC	5	-
DP Documentation & Program Library	1	-
New DP	322	5%
DP Online	18	-
Programming for PDP-15	53	-
Downtime	53	-
TOTAL	5902	

TABLE IX
UTILIZATION IN HOURS OF THE PDP-15/50
1 JULY 1975 THROUGH 30 SEPTEMBER 1976

	1st Qtr. Jul-Sep 75	2nd Qtr. Oct-Dec 75	3rd Qtr. Jan-Mar 76	4th Qtr. Apr-Jun 76	5th Qtr. Jul-Sep 76
Systems Development	339 (45%)	142 (20%)	121 (15%)	174 (24%)	186 (27%)
In-House Users	128 (17%)	256 (35%)	252 (32%)	256 (34%)	185 (27%)
Outside Users	89 (12%)	130 (18%)	209 (26%)	198 (26%)	179 (26%)
A/D Conversion	147 (19%)	127 (18%)	164 (21%)	43 (6%)	40 (6%)
Hardware Failure	23 (3%)	37 (5%)	35 (4%)	54 (7%)	44 (7%)
Preventive Maint.	32 (4%)	29 (4%)	19 (2%)	23 (3%)	46 (7%)
TOTAL USE	758 (100%)	721 (100%)	800 (100%)	748 (100%)	680 (100%)

III. PROGRAMMING

The programming staff at the SDAC used two IBM 360/40 computers, an IBM 360/44, and a DEC PDP-15/50 interactive processor to support all in-house activities including those of the research and data services groups, VSC, and Texas Instruments. The following is a review of that support.

CCP

The Communication Control Processor was accepted by the government during the contract period. Several programmers attended training sessions on the CCP software presented by Bolt, Beranek and Newman employees. Subsequently, we made several corrections and additions to it as follows:

- A utility program was written for the CCP as a training exercise for programmers. The program causes input typed on the CCP monitor teletype to be copied by the CCP paper tape punch. The tape will contain operator commands to be read into the CCP at system initialization time;

- Release 2-5 was modified to change temporarily the default backup data recording mode from the DP to the Seismic Input Processor (SIP). This release was also modified to disable the ILPA and ALPA modules. These modules were suspected to have been responsible for excessive synchronization errors in the LASA processing module.

- Release 2-6 was corrected. The program was incorrectly processing NORSAR status data and flagging all NORSAR LP data as suspect.

- A patch was made to the CCP operational program to count the NORSAR DP detections to help determine why NORSAR was experiencing periodic data outages.

IBM 360/44

The 360/44 performs the bulk of the batch processing done at SDAC. This computer supported the following operating systems during the term of the contract; IBM's OS MVT Release 21.7, IBM's DOS Release 26.2 with Software Design's GRASP spooling package, and TS44 (an IBM P.S. system modified by members of the Engineering Computer Laboratory at the University of Southern California). Throughout the reporting period the use of DOS was de-emphasized with TS44 being used as the replacement. Following these guidelines, the following programs were converted from DOS to TS44:

M7AF	a multi-faceted processing system for the SDAC data tapes.

SUBSAC	a program to merge SDAC subset tapes.
SUB2BCD	a program to convert SDAC subset tapes to BCD card image tapes for external users.
QUERY	an information retrieval system for seismicity data files.
CONVT3	a program to convert tapes written by the CDC 1604 to IBM compatible formats.
SEISFILE	a seismicity file maintenance program.
PLTTPS	a program to plot seismic waveform data from SDAC subset tapes.
CAM	a map generating program.

Several new programs were developed to run under TS44:

TGSI	a program to read VELA archive format tapes and to create both a plot and an SDAC subset tape.
QC2	a program to ascertain the quality of data recorded on tape by the Detection Processor (DP) system.
DPBEAM	a program to create signal beams of new DP data. Capabilities include phase rotation of seismic sensor data, beam forming, plotting, printing and the ability to edit data used by setting different levels of acceptance based on data quality.
SROCOPY	a program to copy SRO field tapes by multiplexing 26-hour segments from each station on a single output tape.
OLDPCY	a program to copy selected time segments from ISRSPS DP tapes. The program can copy both high-rate and low-rate tapes.
NEPBULL	a program to create Preliminary Event Summary File (PESF) format tapes for subsequent transfer to the Mass Store. The input for the program is the output from the two-station hypocenter routines of NEP.

Numerous subroutines were also written for TS44 which concerned tape manipulation and tape error recovery procedures. The routines were designed to allow flexible access to tape data recorded in many formats, and were used in programs written to support research activities and data services.

Maintenance of the TS44 system covered enhancements such as:

- The addition of the PL360 compiler used by the Research Programming Staff.
- The plot package was modified to reduce the time required to plot data.
- Disk files containing frequency and phase response data for the Long Period Experimental (LPE) stations were created. A subroutine, RSP, was created to allow user access to the files.
- A system routine to trace TS44 job control blocks was added as an analytical tool.
- A routine to allow system programmers to control the 360/44 memory from remote terminals was written. This routine helps during times when the TS44 system is blocked by ARPANET protocol difficulties.

Corrections of and refinements to the TS44 system were:

- The linkage editor was changed to correct an error. The editor now accomodates 40 program control sections whereas, prior to the correction, only 18 were obtainable.
- The TS44 Network Control Program (NCP) was changed to accomodate new communication protocols used by the ARPANET.
- TS44 was modified to recognize aliases for commands to allow more meaningful command names.
- Tape error handling routines were altered to reduce operator console input/output time, thereby reducing error processing time.
- From July 1975 until October 1975 the NORSAR daily bulletin was kept on disk file and updated routinely.

This procedure allowed the data to be accessed by anyone who had access to an ARPANET terminal.

In October 1975 we were able to provide minimal support on the 360/44 under IBM's OS MFT operating system. After trying to create a workable OS system, we determined that IBM had delivered a bad OS starter system. Corrections were made to the starter system and the MFT system was generated.

The OS system was upgraded to IBM's MVT release 21.7. This version of OS is more powerful than the MFT system it replaced. The MVT system features more efficient utilization of core memory and it is easier to operate. This system has been tailored to support work in a secure environment. Since its implementation, the following tasks have been accomplished:

- The FORTRAN IV LEVEL H compiler was added to provide diagnostic services to the NEP group.
- TEXT360, a sophisticated documentation system, was installed.
- A library of utility routines was acquired and added to the system. Initial attempts to install these routines revealed incompatibilities which were later resolved.
- An ALGOLW compiler was added.

During the report period, the DOS system was fully supported until August 1976. After that date, system support and maintenance were discontinued. The GRASP spooling package was upgraded at six-month intervals as new releases were distributed to us. In August 1976, the GRASP package was discontinued. Also in August Release 26.2 of DOS was made available. The discontinuance of GRASP demanded extensive disk library re-organization.

We augmented the 360/44 in September 1976 with two additional CALCOMP 2314 disk drives. This action has eased the demand for disk storage by the TS44 users and has enhanced the performance of TS44 and the OS operating systems. Several system generations were done to integrate the new drives into the operating systems.

The station coordinate disk files were routinely updated on each of the operating systems as new data became available.

Efforts to establish communications with the Computer Corporation of America (CCA) while using the TS44 operating system were hindered by what was analyzed as a problem at the Mass Store maintained by CCA in Boston.

The CCA NCP was generating improper ARPANET transmission formats for host-to-host communication data. The design of the NCP in TS44 caused it to be sensitive to CCA's protocol violation. Whenever an attempt was made to establish communications with CCA, TS44's NCP became congested trying to report the errors which in turn interrupted TS44's terminal support and greatly inconvenienced the users. The problem was corrected by CCA in October 1976.

360/40A

The 360/40A system was dedicated to running the real-time Detection Processor (DP) in April, 1976. The DP system processes data from the Large Aperture Seismic Array in Montana and routinely records these data plus other information by writing time series on tape. Windows of data representing possible detections are recorded on disks and are available for further processing by the 360/40B. Information pertaining to the possible detections is then forwarded to receiving agencies via the ARPANET and the Communication Control Processor.

Since its acceptance, DP has been running 20 hours per day with the remaining four hours a day being scheduled for testing of the CCP. The following are augmentations or corrections made to the operational system:

- A problem of an abnormally large number of I/O errors on the output tapes was analyzed and corrected. In this case we found that the IBM hardware was erroneously reporting errors. The real errors remaining after masking out the false ones were corrected by implementing more sophisticated error-handling algorithms.

- The ability to detect end-of-tape conditions was improved.

- On 1 October 1976, NORSAR reconfigured their seismic array, and the changes caused the NORSAR DP results on the Signal Arrival Queue to be incorrect. To correct the problem, a new beam set was requested from NORSAR.

360/40B

The 360/40B was dedicated largely to the development and testing of code for the Network Event Processor. Other uses for this computer are described in Part II of this report.

Numerous system generations of the Disk Operating System were accomplished to:

- Support the HALT I/O command to the operator console.

- Support the asynchronous I/O to the console while preventing the loading of transient routines by the system attention routine.

- Support the system files on disk.

- Correct the SVC8 and SVC9 routines which control system transient routines.

- Add macros for Indexed Sequential Access Method of I/O.

- Correct problems of unassigned devices.

- Add standard system assignments to reduce the amount of Job Control Language required to run jobs. Release 26.2 was generated. This release supported a 2314 disk system instead of the smaller 2311 disk system. Changes were made to allow utilization of the printer/reader/punch on the 360/40A by the 360/40B.

Other programming for the 360/40B involved program development and maintenance such as:

- The addition of a system macro DTFCPMOD to support the PL360 compiler.

- The creation of a program to read the disk file generated by the linkage editor and build catalog subroutines into private disk libraries.

- A macro, ENQDV, was written to provide asynchronous hardware interrupt support for any device in the system.

- A program was written to allow the PDP-11/35 to list programs on the 360/40B printer.

- Program PRTSAQ was written to print the contents of the Signal Arrival Queue.

The remaining programming for the 360/40B system supported the NEP development as follows:

- The program which plots the NORSAR EP results was upgraded by adding error statistics to the plot annotation.

- A data file which contains seismic region information was created on the NEP 2314 disks. A subroutine to associate this information with a given latitude and longitude was also written.

- The NORSAR beam set information in the SAQ test data base was corrected using the 360/40B system.

- IBM's Project Control System was made available to the NEP development team for use in scheduling tasks.

- A feasibility study was conducted to read and write to a terminal from the 360/40B via the 2701 TWX adapter. The study verified the capability.

- A program to spool data to and from the PDP-11/35 was written. The program allows the transfer of card, tape, or printer information. In addition, the program runs in a foreground memory partition and runs on a non-interference basis with background development.

PDP-15/50

Programming for the PDP-15/50 Interactive Processor mainly involved coding a program to generate report quality plots for the Special Data Collection System (SDCS) event reports and support of data services by coding a program to copy selected time windows from Long Period Experiment (LPE) field tapes. The support of the SDCS project also involved maintenance of the Seismic Waveform Analysis Package (SWAP) which was used to pre-process the SDCS data prior to plotting.

The following programming was also done to support the SDCS effort:

- The original report generator was designed to read subset tapes created by the A/D system from SDCS analog tapes. It allowed the analyst to scale data, to rotate horizontal sensor components, to fill bad data segments with zeros and to de-spike data.

- The plot labeling conventions were changed several times and timing scales were added.

- The I/O section of the program was altered to allow creation of multi-file plot tapes.

- The plot section was changed to prevent trace overlaps when more than five data traces were plotted.

- In February 1976, a new program, SDCS4, was written to allow digital tapes to be input to the report generator. Interactive data selection, calibration, and subset capabilities were added to SDCS4. The option to reverse sensor polarity was added to the plot generator.

In August 1976 the program to copy LPE tapes was adapted to allow multitasking on the PDP-15. This allows developmental programming to occur concurrently with the tape copying.

Further work on the PDP-15 involved writing a program to read Seismic Research Observatory (SRO) tapes and graphically scroll through the data using the VT15 console. Additionally, amplitude measurements of signal strength can be calculated interactively based on signal selection by the user.

Two system generations of the Disk Operating System were performed as part of the system maintenance and a program to flowchart FORTRAN programs using the Calcomp plotter was installed during the contract period.

Modifications were made to the program which produces the plots of LASA data on the VARIAN electrostatic printer/plotter to correct errors in demultiplexing and to interpolate graphic data linearly so that the plots simulate those made by a pen plotter.

Two programmer aids were added to the Monitor Console Routine under the RSX III operating system. These aids allow the manipulation of tapes from the operator console and give the operator the ability to dump the information contained in memory onto the printer under operator control.

The following changes were made to the SWAP system:

- Program GRABSUB was changed to correct the seconds and tenths of seconds for a user time request.

- A feature was added that allows users to identify themselves to the system thereby keeping their data files in individual disk libraries.

- The ability to read SRO and SDCS data was added. The time displayed on traces shown on the VT15 was corrected and the direction of motion in response to changes in the graphics control dials (VCD's) was corrected in the Display Manipulation Phase (DMNIP).

- The Analysis Phase (ANAP) was made smaller and the following features were added:

  Data despiking
  Bandpass filtering
  Rotation of phase
  Calibration ability from digital counts to units of ground motion
  Graphic display of processed data
  Ability to write processed data on DECTAPE

Documentation

The following programs and system enhancements were documented:

DPBEAM - a beam-forming program (Draft of User's Guide, only)

PDP7CV - a program to process PDP7 LASA backup tapes

ENQDV - a system macro for DOS

NTXIT - a system macro to swap the action of the system attention button with that of the operator console request key.

The documentation for NTXIT is in the form of a memo to the potential users. At the close of the contract full documentation for DPBEAM, PDP7CV and ENQDV was in the hands of the documentation coordinator.

On two occasions copies of the LASA Processing System were made on disk for the LASA Data Center in Billings, Montana.

IV. MAINTENANCE

During the contract period Geotech maintained the analog laboratory equipment, terminals, incremental plotters, timing systems, communications modems, ARPANET interfaces, the NEP graphics system and its interface, and the Communications and Control Processor (CCP). The remainder of the SDAC equipment was maintained by contracts with local field service organizations.

The following tabulation shows the major equipment changes made during the contract.

Quantity	Description	Date
	DELETED EQUIPMENT	
1	IBM Special Processing System	Jul 1976
1	IBM Experimental Operations Console	Jul 1976
2	Honeywell LAR 7400 Tape Unit	Mar 1976
1	DEC 5-133 Oscillograph	Mar 1976
	ARPANET CHANGES	
1	Replacement of TIP with 316 IMP	Aug 1975
1	Installation of Pluribus IMP	Sep 1975
1	Disconnection of 316 IMP	Dec 1975
	GFE ACQUISITIONS	
1	BB&N Communications & Control Processor	Apr 1976
5	CDI Telterm 1030 Terminals	Jul 1975
	FABRICATED UNITS	
1	Analog Time Mark Generator	Aug 1975
1	Automatic Bootstrap Panel for PDP-11/35	Sep 1975
1	Battery Power System for TOD Clocks	Dec 1975
1	Serial Interface Clock	Aug 1976

The CCP replaced the IBM Special Processing System which was removed from the SDAC computer room.

The NEP graphics system replaced the IBM Experimental Operations Console which was also removed.

The Develocorders formerly used to monitor ALPA and LASA long-period data were functionally replaced by a storage tube terminal which is connected to the CCP.

IN-HOUSE MAINTENANCE

Analog Laboratory

The only addition to the analog laboratory was a time mark generator which produces hour, minute, or 10-second marks from the VELA serial BCD time code.

Several pieces of equipment which were seldom used have been removed from the analog laboratory, reducing the complexity of the laboratory. The remaining analog equipment was maintained in an operational condition including the equipment necessary to make oscillograms, perform A/D conversion, and copy or compress analog field tapes.

NEP Graphics System

The NEP graphics system consists of the Evans & Sutherland Picture System, a Digital Equipment Model PDP-11/35 computer, an Ann Arbor cathode ray tube alphanumeric terminal, a Computer Labs dual cartridge disk, a dual digital cassette unit, and the Model 1140 interface to the IBM 360 computers.

The problems encountered with the 1140 interface between the NEP graphics system and the IBM 360 computer were primarily due to logic errors in the hardware design and to a lack of test programs.

Hardware failures in the NEP graphics system were associated with memory, the central processor, a terminal display unit, a cassette unit, and the graphics processor. The failures were simple component failures for the most part as opposed to those resulting from poor design or construction.

The diagnostics and documentation delivered with the PDP-11/35 are excellent. The documentation for the E&S picture system is adequate, and the E&S diagnostic routines are thorough. The documentation delivered with the Computer Labs disk system is very good.

The automatic bootstrap panel fabricated for the PDP-11/35 speeds the system initiation by eliminating the need for a beginning address selection on the console.

The serial interface clock was built to accomodate a higher speed terminal in place of the ASR33 teletype.

CCP System

A maintenance training course was given for SDAC personnel by the equipment supplier prior to our acceptance of the maintenance responsibility. The failures of the CCP system were due to component failures and faulty connections on the card edge connectors. The documentation delivered with the system is good. The overall system diagnostic and exerciser (HIT) failed to find hardware problems on two occasions.

No maintenance documentation was delivered for the Tektronix 4610 hardcopy device and the Codex 4800 modems. These manuals were acquired.

The Tektronix 4010 terminal used as a data monitoring device shows rapid degradation of the CRT phosphor when the unit is left in continuous operation. The CRT was replaced after approximately six months of service and the new CRT shows signs of phosphor burn after two months of service.

A battery power system was added to eliminate the need for resetting the TOD clock immediately after an AC power failure. The CCP program will not accept data if its TOD clock is improperly set.

Terminals

Five terminals in addition to those dedicated to the NEP graphics and CCP systems were maintained by Geotech. The remainder of the terminals at SDAC were maintained by the manufacturer or the lessor. Response to trouble calls for the Hazeltine, Computer Devices, and Western Union terminals was good resulting in more reliable service from the devices.

CONTRACT MAINTENANCE

Air Conditioners

An increasing number of compressor failures and difficulty in finding direct replacement parts for the EDPAC units led to discussion with the air conditioner service contractor concerning the expected life of the present equipment. The advice given was to begin replacing the present units two at a time over the next three years. The air conditioner failures and an increase in computing equipment in the 360/44 computer room led to some 360/44 system down time during the summer months when the room temperature reached 80°F.

The present contractor responded well to trouble calls and made arrangements for service work even when his regular employees were on strike.

PDP-15

The major problem areas with the PDP-15 during the contract period were magnetic tape unit failures and graphics console problems.

DEC field service personnel were adequate in their performance; however, on more than one occasion during the contract period the system was partially inoperative for several days while awaiting delivery of spare parts. In response to repeated failures of the Bucode tape units, DEC called in an expert from the manufacturer to give advice on changes and preventive maintenance procedures.

IBM Equipment

The reliability of the IBM central processors and peripheral equipment with the exception of tape units continued to be good. Excluding scheduled PM, the 360/40 machines were operative 99.6% of the time. The 360/44 was operative 96% of the available time, excluding PM.

Difficulties with the magnetic tape drives are an outstanding problem with the IBM equipment at SDAC. Field service personnel continue to rebuild the existing tape units and perform preventive maintenance on the units on a regular basis. It should be recognized that increased emphasis must be put on the magnetic tape unit maintenance and on quality control of the magnetic tapes used, if reliable data recovery is to be achieved.

Disk Systems

The Memorex 3660 disk system was maintained by Memorex personnel. No major equipment failures occurred during the contract.

The Calcomp CD-14 disk system was maintained by Calcomp personnel. No major problems were encountered during the contract period. Two additional rented disk drives were added to the system to improve the TS-44 operating system performance.

MAINTENANCE PLAN

A maintenance plan was written which describes the equipment in the expanded VELA network at SDAC. This document specifies who maintains each piece of equipment, the schedule for preventive maintenance, how and by whom the maintenance logs are completed, how spare parts are cataloged, and review procedures to insure that the equipment is being properly maintained.

Most of the procedures in the maintenance plan were in effect by the end of the contract period.

V. SERVICES

During the report period, we provided facilities and services to the VELA Seismological Center and to Texas Instruments as specified in Task 4.4 of the Statement of Work.

In partial fulfillment of Task 4.4 we also provided computer and data services to other government agencies and to contractors who are participants in the VELA program. We used the IBM 360/44 and 360/40B computers and the DEC PDP-15/50 system to accomplish the work. The institutions listed below received these services in one form or another during the period covered by the contract.

Atomic Weapons Research Establishment, Blacknest
Bolt, Beranek & Newman, Inc.
California Institute of Technology
Catholic University
Department of Energy, Mines, and Resources, Ottawa
ENSCO, Inc.
Georgia Southwestern College
Hagfors Observatory, The Research Institute of National Defense, Stockholm
International Seismological Center, Scotland
Institute of Geological Sciences, Edinburgh
Lamont-Doherty Geological Observatory
Massachusetts Institute of Technology
National Geophysical & Solar-Terrestrial Data Center, Boulder, Colorado
Naval Postgraduate School
NOAA, Environmental Data Service
NORSAR
North Dakota Geological Survey
Pennsylvania State University
Princeton University
Purdue University
Research Institute for Protective Construction, Zurich
Scripps Institute of Oceanography
Seismological Institute, Uppsala
Southern Methodist University
St. Louis University
Swiss Institute of Technology, Zurich
Systems, Science and Software, Inc.
Tennessee Valley Authority
Texas Instruments
The Australian National University

University of California, Berkeley
University of California, Los Angeles
University of California, San Diego
University of Connecticut
University of Oklahoma
University of Oregon
University of Tennessee
University of Texas, Dallas
University of Texas, Galveston
University of Toronto
University of Western Ontario
U. S. Arms Control and Disarmament Agency
U. S. Geological Survey
Virginia Polytechnic Institute
Weston Geophysical Research, Inc.

To satisfy the requirements of individual requestors, and to assure that valid data and supporting information such as logs and calibrations were delivered, we:

-- maintained lists of data tapes and updated these continuously;
-- employed access procedures to expedite data identification and retrieval;
-- verified data requests and A/D conversions;
-- filed data plots;
-- maintained the Long Range Seismic Measurement (LRSM) tape and film libraries;
-- received data from outside sources and maintained shipping records; examples of data sources are SRO and HGLP stations, ILPA, KSRS, and NORSAR;
-- maintained and updated lists of instrument response curves, array configurations, and station locations; and
-- kept a library of seismicity data from several sources including lists from France, Sweden, and Scotland.

During the report period, we filled 207 formal data requests. In addition to these, we completed informal requests for research scientists at the SDAC and for VSC personnel.

The Lincoln Laboratory at the Massachusetts Institute of Technology was the principal outside user of data provided by the SDAC. At the beginning of the contract period their scientists requested ALPA, NORSAR and LASA data converted to either External Users Format or FFASTRO format. The level of requests varied from month to month and averaged about twenty events per month. Beginning in 1976 almost all data requests from Lincoln Labs involved SRO data.

Another principal user was the Naval Postgraduate School in Monterey, California. In this case the number of events was small compared with that of the Lincoln Laboratory; however, much time was required to form infinite velocity subarray beams and to convert the output to BCD format.

In January 1976 SDAC began to receive tapes routinely from three SRO stations, which were Albuquerque, New Mexico, Guam, and Mashad, Iran; and a plan to make SRO day tapes was developed. A day tape is twenty-six hours of data beginning about zero hours GMT on the date of interest and ending about 0200 hours on the following day. During the reporting period, about 35 such tapes were made.

Comprehensive seismicity data are gathered by the National Earthquake Information Service in the United States and by other governments such as the Institute for National Defense in Sweden, the Atomic Energy Commission of France, and by the Royal Norwegian Council for Scientific and Industrial Research. Seismicity lists submitted to us by these governments are transformed at the SDAC to digital data and are written on magnetic tape. Program SEISFILE is used to collate these epicenters and program QUERY facilitates access to the events by searching for prescribed source parameters.

VI. SEISMOLOGICAL RESEARCH

During the 15-month period ending 30 September 1976, scientists and support personnel in the Research section at the SDAC completed 18 technical reports, 10 memoranda, and two special studies, all on the subject of seismology. The technical reports and the special studies were distributed to the government-approved list. The memoranda were distributed to members of the research staff at SDAC and to the VELA Seismological Center. In addition, two professional papers were cleared for publication in a technical journal, and three papers were cleared for oral presentation at meetings of professional societies.

Summaries of the distributed reports, titles of the memoranda, and titles of papers cleared for publication or oral presentation follow:

SHORT-PERIOD SIGNAL-TO-NOISE RATIO AT NORSAR (SDAC-TR-74-13)

In this study nine seismic events recorded by the NORSAR short-period array were beamformed in different ways to determine the effect of the number and location of sensors on the efficiency of NORSAR beams. The study reveals that a beam of the ten Northeast subarrays has only .06 magnitude units less detection capability than the full array and that the 3C subarray has only .18 magnitude units less capability. We show that if the 3C subarray were expanded to 56 elements inside a 15-km diameter circle it would have .3 magnitude units more detection capability than the present full array.

DETECTION OF LONG-PERIOD S FROM EARTHQUAKES AND EXPLOSIONS AT LASA AND LRSM STATIONS WITH APPLICATION TO POSITIVE AND NEGATIVE DISCRIMINATION OF EARTHQUAKES AND UNDERGROUND EXPLOSIONS (SDAC-TR-74-15)

An improved distance-amplitude relation for long-period shear (S) waves is developed and applied to the seismic shear phase from megaton-range explosions. We find that the difference between magnitude determined from the maximum amplitude long-period S waves and the magnitude determined from Rayleigh waves is a good discriminant between worldwide earthquakes and explosions at NTS and Amchitka. The long-period SH/SV ratio is not a discriminant.

The 90% incremental threshold for detection of earthquake long-period S waves at LASA from Japan and the Kuril Islands is $m_b = 5.2$. Beamforming and frequency-wavenumber analysis were found to be equal in detection capability. Strauss (1973) reported data which imply a threshold of $m_b = 4.7$ for detection

of long-period S waves at ALPA from the Kuril Islands and Kamchatka. The difference between LASA and ALPA capability can be explained by the average distance-amplitude relation together with the lower noise level at ALPA.

For a possible seismic network (Romney, 1971) the use of negative discriminants (no detection of S waves) with .01 probability of a false alarm for explosions is shown to result in an M_S threshold approximately equal to the threshold of 90% probability of detection of S waves from earthquakes by two or more stations (positive discrimination). A significant lowering of the negative threshold is possible if one station of the network has an especially low detection threshold.

CHARACTER OF VERTICAL-COMPONENT SIGNALS AT HIGH-GAIN, LONG-PERIOD STATIONS AND SIGNAL INTERFERENCE ON SEISMIC DETECTION NETWORKS (SDAC-TR-75-1)

To approach the problem of simultaneous arrivals of two or more seismic signals at a particular station, we measured the amplitude and period of over 600 long-period vertical-component seismic signals at regular intervals in order to characterize the Rayleigh wave (LR) signal and its coda. Signal envelopes out to 20 minutes after LR onset were found to vary considerably, but coda amplitudes decayed rather uniformly with time. Using average signal and coda parameters and randomly-generated events, we simulated long-period signal interference at seismic stations and predicted interference effects on network detection statistics. We conclude that increasing the size of a network should not increase the number of reported events with interference at any M_S, but lowering the station thresholds will increase this number at lower M_S values.

ADDITIONAL INVESTIGATION OF EARTHQUAKES WITH LOW M_S-m_b RATIOS IN THE TIBET-HIMALAYA REGION (SDAC-TR-75-2)

This report extends the work reported in SDL 286 in which the M_S vs. m_b characteristics of certain earthquakes in Asia were studied. Further analysis of the anomalous events in the eastern Himalaya region with an expanded set of stations shows that the M_S values of these events are indeed low compared to m_b. Other characteristics of these events indicate, however, that all are earthquakes rather than explosions. Dilatational first motion for P waves, long-period S to Rayleigh, short-period S- to P-wave amplitude ratios are characteristic of earthquakes. Readings of the pP phase where available as well as epicenter calculations indicate that the anomalous event hypocenters are shallow, i.e., less than 80 km. Data quality did not permit the refinement of epicenter locations.

A search for additional anomalous events with respect to M_S-m_b in a wider area in the Himalayan-Tibet region indicated that there are no other contiguous areas containing anomalous events in this region beyond those already found.

Q FOR 20-SECOND RAYLEIGH WAVES FROM COMPLETE GREAT-CIRCLE PATHS (SDAC-TR-75-3)

This report examines the amplitude-distance relation of Rayleigh waves, because of its importance in estimating surface wave magnitudes. Seismograms of carefully selected large earthquakes recorded on the high-gain, long-period network were used to determine visually the amplitude ratio of 20-second Rayleigh waves in the R_1 and R_3 phases. Identification of R_3 was aided by applying a time-varying processor which discriminates heavily against ground motion other than the R_3 signal. Ratios were determined in 29 cases representing diverse great circles over the earth; the average Q estimated for the 20-second, fundamental-mode Rayleigh waves was 498. This value is relevant to distance-amplitude corrections routinely made in M_S calculations and is significantly greater than that Q implied by the current $1.66 \cdot \log\Delta$ relation. Our data did not reveal any significant difference in attenuation over oceanic and continental structures for 20-second Rayleigh waves.

USE OF SOURCE-REGION STATION-TIME CORRECTIONS AT NTS FOR DEPTH ESTIMATION (SDAC-TR-75-4)

Positive hypocenter determination is useful in discriminating between earthquakes and underground nuclear explosions. Travel-time residuals may be obtained from a least-squares location program which is run with the depth constrained to the known "true" value. When these residuals are used as travel-time corrections in the same program run depth-free, nearby events are located with smaller errors in depth. An elaboration of this technique has been denoted the SRST (Source-Region-Station-Time) technique by K. Veith.

In this study we have applied the technique to Nevada Test Site (NTS) explosions. The mean estimated depth is changed from approximately 50 km to approximately 0 km with standard deviations of 30 km for a well-distributed 5-station network, and 20 km for a 9-station network.

We point out that the technique can be in serious error if deep earthquakes are used to determine residuals for shallow explosions in a source area where the earth structure between the earthquake and surface is different from that implied by the travel-time table used.

We also show that there is no evidence for change of travel-time residuals with time for arrivals from NTS at RKON, NPNT, BUL, and PRE. There is, however,

evidence that significant changes in residuals are correlated with location at Pahute Mesa and that the changes may be due to interactions with a deep volcanic plug under Pahute Mesa.

PERFORMANCE OF THE PHILTRE PROCESSOR AT LOW SIGNAL-TO-NOISE RATIOS (SDAC-TR-75-6)

In this report we show that a non-linear, adaptive processor called PHILTRE is useful in detecting long-period Rayleigh waves in various low signal-to-noise ratio situations such as signals buried in noise at various levels, two mixed signals from different azimuths and with different amplitudes, and visually undetected signals recorded at LASA, ALPA, and NORSAR from the Kurils-Kamchatka region.

PHILTRE lowered the detection threshold for Rayleigh waves buried in noise by about 6 dB. It was able to separate two signals if their azimuthal separation was greater than 60 degrees, and if at the same time the amplitude of the second signal was at least 20 percent of the amplitude of the first signal. It lowered Rayleigh-wave 50% detection thresholds by roughly 0.2 m_b unit at the three long-period arrays.

APPLICATION OF THE INTERATIVE BEAM PROCESSOR TO LONG-PERIOD RAYLEIGH WAVES (SDAC-TR-75-8)

In an effort to separate signals arriving simultaneously at a seismic array, we evaluated the iterative beam processor. This technique assumes that the directions of the two sources are known. An estimate for the first event is obtained by steering the array toward the first epicenter. The resulting trace is subtracted from all traces which are then beamed to the second epicenter to obtain an estimate of the second signal. This estimate is also subtracted from the original traces which are then rebeamed to the first epicenter to improve the estimate of the first signal. Repetition of this procedure theoretically yields maximum likelihood estimates for both signals.

The technique was applied to superposed recordings of Rayleigh waves at LASA. It was found that multipathing of Rayleigh waves can cause enough leakage into the beam of the desired event to make the separation impossible if the amplitude of waves from the event to be eliminated is more than three times that of the event of interest.

THE EFFECT OF BANDPASS FILTERS ON LASA DETECTION PERFORMANCE (SDAC-TR-75-9)

On-line testing at the SDAC of short-period automatic detection filters in the bands 0.9-1.4 Hz, 0.9-1.8 Hz, 0.8-1.8 Hz, and 0.8-2.5 Hz reveals

statistically insignificant differences in the number of events reaching the LASA summary bulletin from the automatic processor.

Almost all detections which do not reach the summary bulletin are due to multiple picks on regional events. Therefore, a substantial lowering of the analyst workload or a substantially lowered threshold would be possible, if a reliable procedure were developed to flag detections due to regional events.

An excellent correlation was found between the number of events per hour which reach the summary bulletin and the hourly noise level.

SHORT-PERIOD EARTHQUAKE CODA SHAPE AS A FUNCTION OF GEOLOGY AND SYSTEM RESPONSE (SDAC-TR-75-10)

To investigate the problem of hiding the signature of an underground nuclear explosion in the coda of an earthquake, we obtained measurements from recordings of 33 earthquakes which show that some Long Range Seismic Measurement (LRSM) stations have high levels of short-period coda as compared to maximum motion, and that reverberation between successive coda maxima is less at stations overlying a low-Q mantle than at those overlying a high-Q mantle. The differences are 0.1-0.2, and 0.1 magnitude units respectively. For times greater than 1 or 2 minutes into the coda, minimal coda levels are typically 0.3 magnitude units less than the maxima. Comparison with work by Filson shows that use of the maximum coda representation could lead to a 0.2 m_b underestimation of the detection capability for mixed events for times greater than 2 minutes. There seems to be no difference in coda shape measurements made on data recorded at WWSSN or LRSM systems.

VARIABILITY OF SEISMIC WAVEFORMS RECORDED AT LASA FROM SMALL SUBREGIONS OF KAMCHATKA (SDAC-TR-75-12)

A comparison of LASA short-period waveforms from earthquakes in three 1° diameter circles on capes of Kamchatka reveals that there are substantial differences in the typical waveform from each circle, and that both simple and complex events originate within each circle. A total of 65 events was examined. Only a few events, all from one region, have emergent waveforms which Kolar and Pruvost (1975) have suggested are required for successful simulation of an earthquake by an array of explosions. Several events were found with M_s only slightly greater than m_b - 1.5, the region of the M_s:m_b plane typical of explosions. The low values of M_s-m_b and compressive first motions at LASA, together with published fault plane solutions from the area suggest that those events are from 45° thrust faults. Defining m_b on the maximum amplitude in the first 10 seconds of the short-period signal would be a useful shot

array countermeasure. The result for earthquakes is a slight tightening of the M_S:m_b population, and no increase in events with M_S near m_b - 1.5. An m_b measuring more closely the total emitted radiation in 10 seconds seems physically reasonable and results in even tighter clustering, but for complex events does generate m_b values such that $M_S < m_b - 1.5$.

USE OF EARTH RESOURCES TECHNOLOGY SATELLITES (ERTS) TO DETERMINE TECTONIC CHARACTERISTICS NEAR LOW M_S-m_b EARTHQUAKES IN TIBET (SDAC-TR-75-13)

Examination of Earth Resources Technology Satellite (ERTS) photographs suggests that faults intersect within 10-20 kilometers of the NEIS epicenters of a cluster of low M_S-m_b events in Tibet. This suggests that the low M_S values which tend to place the events in the explosion population may be due to some tectonic cause, for example dip-slip thrust faults having high stress drop and small fault-plane areas dipping about 45° which have been shown by Douglas to have low M_S-m_b. Therefore, unless the faults are steeply dipping the low M_S values cannot be traced to attenuation of the Rayleigh waves due to great depths of the hypocenters.

DISTANCE-AMPLITUDE RELATIONSHIPS FOR LONG-PERIOD P, S, AND LR FROM MEASUREMENTS ON RECORDINGS OF THE LONG-PERIOD EXPERIMENTAL STATIONS (SDAC-TR-75-14)

To improve estimates of body- and surface-wave magnitudes, we measured amplitudes of long-period P, S, and LR phases on seismograms in an eight-month data base for nine stations of the Long-Period Experimental network. Amplitude-distance curves were plotted for P and S from shallow-focus events; these curves generally agree with the commonly-used Gutenberg-Richter B factors. The amplitude-distance curve for LR was different in slope than the commonly-used correction curve for M_S; however, this difference would not be sufficient to affect routine network M_S estimates by more than roughly .1 magnitude unit. The Q for 20-second LR implied by this new data is roughly 700, in contrast to the 300 implied by the accepted amplitude-distance curve.

HIDE-IN-EARTHQUAKE COUNTERMEASURES USING EARTHQUAKE P SHADOW ZONE AND EXPLOSION PKP CAUSTIC ZONE (SDAC-TR-75-15)

Established distance-amplitude curves are used in this study to illustrate the feasibility of a method to detect the presence of a seismic phase from an underground explosion in the coda of an earthquake. The advantage of the technique arises from the fact that the amplitude of an earthquake coda is reduced on recordings taken in the core shadow zone while the amplitude of PKP from an explosion is enhanced in its caustic zone.

Results of the study indicate that the method can be effective even if the explosion and earthquake are located only two to five degrees apart.

SHORT-PERIOD P-WAVE ATTENUATION ALONG VARIOUS PATHS IN NORTH AMERICA AS DETERMINED FROM P-WAVE SPECTRA OF THE SALMON NUCLEAR EXPLOSION (SDAC-TR-75-16)

The attenuation in the upper mantle of P waves has important implications for the magnitude-yield relationship. Therefore, in this study we determined average Q values for ray paths to various LRSM stations from the SALMON nuclear explosion, which was located in a salt dome in Mississippi, by taking ratios of observed P-wave spectra to that of the estimated source spectrum. Most average Q values for the SALMON P wavepaths throughout the eastern North America are close to 2000 while those with the last half of their path in the western United States are typically around 400-500. These differences in Q seem to be sufficient to explain the .3-.4 magnitude differences in the teleseismic event magnitude observed in the western vs. eastern United States.

COMPARISON OF REGIONAL ATTENUATION IN EUROPE AND IN THE UNITED STATES (SDAC-TR-76-2)

Seismic events which occur above regions of low Q in the earth's mantle are likely to have lower teleseismic magnitudes with the result that the energy release, or yield in the case of underground nuclear explosions, will be underestimated relative to events occurring in shield areas with high Q.

In the present study a maximum likelihood estimation procedure was applied to observations of short-period P and S waves from deep earthquakes in Europe and in the United States to estimate regional variations in attenuation in the two regions. The separation is much less pronounced in Europe, indicating that the variability of the observations is much less than in the United States. The results indicate that attenuation effects under stations in Europe are not as important as in the United States and therefore that station magnitude biases due to attenuation are not likely to be significant.

ANALYSIS AND REDUCTION OF FALSE ALARMS AT LASA (SDAC-TR-76-6)

In this study "false alarms" recorded by the Large Aperture Seismic Array and detected by computers at the Seismic Data Analysis Center are categorized and analyzed to show the rate of occurrence of each type. As a result, we show that many of the "false alarms" which require analyst intervention in the preparation of the LASA seismic summary were due to local or regional

events. Analysis showed that these false alarms occur predominantly on weekdays during local working hours, suggesting that the seismic events are of man-made origin. The false alarm rate decreases on weekends and holidays, when LASA reports more teleseismic events.

To reduce the number of false alarms it is necessary to steer detection beams to local areas. By detecting local events on these beams and by using a higher S/N threshold in processing these signals, we effectively reduce the number of false alarms from the original 57% to 41%.

A new beam set was developed and deployed which concentrates teleseismic beams in high seismicity areas instead of spacing them equidistantly apart. This arrangement reduced the average detection errors from 200 km to 50 km, and there is some indication of a lowered detection threshold on the order of 0.1 $\pm$ 0.1 magnitude units.

THE EFFECT OF ATTENUATION ON THE SPECTRA OF P WAVES FROM NUCLEAR EXPLOSIONS IN NORTH AMERICA (SDAC-TR-76-7)

The attenuation of seismic waves in the earth affects the relationship between body-wave magnitude and source yield as well as short-period P-wave spectral discriminants. For this reason we measured anelastic attenuation (t^*) along various paths in North America using spectra of P-waves from nuclear explosions PILEDRIVER, KNICKERBOCKER, MAST, GNOME, and SALMON to various LRSM and SDCS stations. The results are consistent with the presence of a sizeable low-Q layer under the western United States (WUS) and the absence of such layer under the tectonically stable eastern part of North America. Typical values of t^* at intermediate distances along paths crossing this low-Q layer are around .45. Paths outside WUS have typical t^* values around .15.

TECHNICAL MEMORANDA

During the contract period, we completed and delivered to VSC memoranda on the following subjects:

"Cube-root Scaling for Contained and Cratering Explosions," dated 8 April 1975

"Effect of Regional Attenuation on m_b Values," dated 15 April 1975

"Evaluation of NORSAR Short-Period Signal-to-Noise," dated 30 September 1975

"Evaluation of NORSAR Short-Period Signal-to-Noise," dated 07 October 1975

"Extension of NORSAR S/N Study to USSR Explosion Sites," dated 09 October 1975

"LASA Detection Threshold - 1 January 1974 - 30 June 1975," dated 09 September 1975

"LASA Detection Thresholds for 1974, Comparison Monday through Saturday, with Sunday," dated 16 March 1976

"Status of LOC2ST as of 6 December 1975," dated 08 December 1975

"Errors in the Hypotrak Delay Time Computation," dated 19 December 1975

"KSRS LP Noise Study - Interim Report," dated 30 December 1975

SPECIAL REPORTS

Two reports based on data gathered by the Special Data Collection Systems were published in September 1976. They are:

SDCS-ER-76-103	Uzbek SSR	17 May 1976
SDCS-ER-76-104	Eastern Kazakh	19 May 1976

PAPERS CLEARED FOR PUBLICATION IN THE OPEN LITERATURE

"Short-Period P-Wave Attenuation Along Various Paths in North America as Determined from P-Wave Spectra of the Salmon Nuclear Explosion" - cleared 05 January 1976 - BSSA

"Amplitude-Distance Relation and Q for 20-Second Rayleigh Waves" - cleared 29 April 1976 - BSSA

PAPERS CLEARED FOR ORAL PRESENTATION

"Short-Period P-Wave Attenuation Along Various Paths in North America as Determined from P-Wave Spectra of the Salmon Nuclear Explosion" - cleared 05 January 1976 - AGU

"Surface-Wave Ray Tracing for M_S Correction" - cleared 14 May 1976 - SSA

"The Relationship Between Anelastic Attenuation and Regional Amplitude Anomalies of Short-Period Teleseismic P Waves in North America" - abstract cleared 14 September 1976 - AGU

VII. VELANET DEVELOPMENT

The objective of the work described in this section is to create an automatic digital system with the capability to receive, process, and store seismic data from remote recording sites. The system elements are the revised LASA Processing System (LASAPS), the new Detection Processor (DP), and the Network Event Processor (NEP). These elements are discussed below after a brief review of a report completed by systems analysts which follows immediately.

THE RTDCOM PROTOCOL - A REAL-TIME INTERCOMPUTER DATA TRANSMISSION PROTOCOL FOR THE ARPA NETWORK (SDAC-TR-75-7)

This document presents an ARPA Network Protocol for real-time high-volume data transmission between computers utilizing prearranged non-switched data communication channels. This protocol deletes unnecessary and cumbersome aspects of the standard (NCP) ARPANET protocol and adds features intended to strengthen data integrity and to avoid error and loss due to network instability and outage. A special feature enables automatic switching of the data channel to alternate IMP ports in case a site changes its configuration. This protocol is suitable for use with either the IMP Regular Message (type 0) or the newly-introduced Uncontrolled Packet (type 3).

LASAPS

In January 1976 the VSC requested that we update General LASAPS Information to include the transmission order of long-period (LP) channels from LASA and to provide scale factors in millimicrons per count for all channels. This information was transmitted to VSC in March 1976 along with certain test data and test procedures which were also requested.

DP

Testing of the new DP system began in October 1975 using inputs from tape, proceeded through November and into December using real-time data from the CCP, and extended into April 1976 to verify detections at the Korean Seismic Research Station (KSRS) using data on tape as shown on the following summary of test results. The final demonstration of the new DP system was given in April 1976 using the NORSAR beam set.

DPS ACCEPTANCE TEST RESULT SUMMARY

DEMO 1	LASA Detection with Tape Input
Test 1	VSC requested a rerun with the output scaled higher so smaller differences could be determined. This was done on 29 October. The test was rerun successfully.
Test 2	Successfully completed on 30 October 1975.
Test 3	Successfully completed on 30 October 1975.
Test 4	Successfully completed on 3 November 1975.
Test 5	Successfully completed on 3 November 1975.
Test 6	Run successfully on 17 November 1975 except that 2nd record was absent from the output tape. Enough of the test was rerun to show that the error was eliminated.
Test 7	Successfully completed on 20 November 1975.
Test 8	Successfully completed on 31 December 1975.
Test 9	Successfully completed on 17 September 1975.
DEMO 2	KSRS Detection with Tape Input
Test 1	Successfully completed on 1 April 1976.
Test 2	Successfully completed on 2 April 1976.
Test 3	Successfully completed on 5 April 1976.
Test 4	Successfully completed on 5 April 1976.
Test 5	Successfully completed on 5 April 1976.
DEMO 3	Real-Time Test with CCP
Test 1	Successfully completed by VSC in November 1975.
Test 2	Successfully completed. Part 1 - January 8, Part 2 - February 28, 1976.
Test 3	Successfully completed on 12 December 1975. There were errors in data but DP processing was verified.

Test 4 Successfully completed on 25 November 1975.

Test 5 Successfully completed on 25 November 1975.

In addition to the tests described above, we delivered to the government documentation of the DP system as shown below:

Operations Reference	26 Nov 1975
Systems Reference	19 Feb 1976
Test Plan	14 Apr 1976
Acceptance Test Results	14 Apr 1976

Schedules showing the progress of the work were submitted to VSC each month throughout the development and finalization of the DP system.

Network Event Processor (NEP)

The effort placed on NEP development during this contract period was directed primarily toward implementing the existing software. Additional hardware previously recommended for NEP was received, installed and accepted during this period. This equipment increases the efficiency of the seismic analyst as he reviews the data. The major components of the additional equipment and their primary functions relating to NEP are:

GRAPHICS DISPLAY - An Evans and Sutherland Picture System is used by the analyst to review and manipulate the waveform data and to make quantative measurements of the seismic signals.

ALPHANUMERIC DISPLAY - An Ann Arbor alphanumeric display terminal helps the analyst review the character data (station, signal, arrival time, amplitude, period) pertaining to the seismic signals.

DISK STORAGE - This is a removable disk cartridge for use in data storage and system development.

MINI COMPUTER - A PDP-11/35 general purpose processor controls the various peripherals configured for the analyst and provides processing capability for computing certain seismic parameters.

INTERFACE - A specially-designed interface connects the PDP-11/35 to the IBM 360/40. The interface provides the analyst with access to both the character and waveform data files maintained on the S360 system.

Software to support the basic functions of these devices was developed. In the case of the PDP-11/IBM-360 interface it was necessary to develop maintenance

software as well as the fundamental routines which enhance the utilization of the hardware.

The software implementation closely followed the approaches recommended during the design phase. The programming effort in developing this system produced files of the seismic waveform, character, and parameter data. Also, the detailed definition of the system interfaces was made and some capability for the interactive display and manipulation of waveform data was achieved.

Numerous demonstrations were given throughout the development of the system. These demonstrations served to validate the software and to provide the government with an insight of the system's capability. The following list summarizes these demonstrations:

DEMONSTRATION	DATE	PURPOSE
40B-44-40B	09 Sep 75	To exhibit the correct operation of the Network Control Program, the MINI-EXEC, the XMIT and RECV processes, and the interface hardware connecting the 360/44 and 360/40B to the ARPA Network and the IMP.
TESTP	08 Oct 75	To demonstrate the correct contents of test data recorded on a DP data tape. These data consist of waveform data from LASA, NORSAR, and the Korean arrays.
40B-Datacomputer-40B	28 Oct 75	To demonstrate the correct operation of the network control program in sending unformatted data to and from the Data-computer.
FPAQ	31 Oct 75	To form the chronological PAQ from the SAQ and demonstrate that no data loss occurs.
LOC2ST	04 Nov 75	To demonstrate program LOC2ST which generates fictitious stations to be used with two actual stations to compute an event location.
INIT	05 Nov 75	To establish the parameter file and demonstrate the flexibility for system updates and parameter modifications.
HYPO	06 Nov 75	To compute an event location and origin time using P and PKP wave arrivals from a selected set of network stations.

TRIX	06 Nov 75	To computer epicenter(s) and origin time(s) using three initial arrivals.
Sequential Queueing	12 Nov 75	To demonstrate the method the processing task selects for execution sequence and the inherent flexibility of the sequencing method chosen.
SAD	24 Nov 75	To show that the DP detections are being flagged as to their probable source as coda, low threshold, or sidelobe detections.
Datalanguage 40B to Mass Store to 40B	15 Jan 76	To show the ability of the NCP component of NEP to send structured data from SDAC to the Datacomputer and receive at SDAC the results of queries made against the data transmitted to the Datacomputer.
PHAZID	28 Jan 76	To show that later phases are correctly identified given an event location and phase arrival parameters.
IBM 360 - PDP-11	30 Jan 76	To demonstrate two-way transfer of data between the IBM/360 and the PDP-11.
Form PAQ	14 Apr 76	To form the Phase Arrival Queue. The purpose of the process is to transfer the DP detections written on the Signal Arrival Queue from the shared disk to the NEP disk. This transfer also results in some preprocessing and classifications of the DP detections.
FILTER	13 May 76	To verify the correctness of the filter algorithms and the correct application of each filter to an arbitrary data channe.
PESF	10 Jun 76	To display the ability of the NCP cor nt of NEP to send data that represents t best approximation of Preliminary Event Summary data that is currently derivable from the NEP test data base. Further, these data, once stored in the Mass Store will be retrieved at SDAC.

NEIS	29 Jul 76	To show the capability for introducing character data into the NEP data file that are comprised of time picks of initial and later arrivals from the NEIS data source.

The demonstrations described above provided the evidence of development progress, and the final goal of a completely integrated system was partially attained. Toward the end of the contract period a seismic bulletin was produced, and the files containing character information for transfer to the mass store were finalized.

Documents containing the following plans and guides were delivered to VSC:

a)	Maintenance Plan (draft)	A00D	15 Mar 1976
b)	Operations Manual (draft)	A00D	1 Jun 1976
c)	Mass Store Data Retrieval Guide (Preliminary Draft)	A00D	30 Jun 1976
d)	Documentation Plans for a, b, and c above (original)	A00H	18 Aug 1975
e)	Documentation Plans for a, b, and c above (revised)	A00H	16 Oct 1975
f)	NEP Acceptance Test Plan (Version 1)	A00K	1 Apr 1976
g)	NEP Acceptance Test Plan (Version 2)	A00K	20 Apr 1976

In addition to the above, the NEP team prepared drafts of the following documents for delivery early in October and November.

NEP Analyst Guide
Final Acceptance Test
Acceptance Test Results Manual